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The dynamic responses of the of the submerged floating tunnel under seismic effect

DONG Man-sheng*[1], LI Man

School of Transportation Engineering, Hefei University of Technology, Hefei 230009, P.R.China

Abstract

Based on the theory of elastic foundation beam, dynamic equations of submerged floating tunnel(SFT) tube under seismic force are presented. For investigating the influence of P wave, tunnel length and stiffness of anchorage system on SFT tube, the nonlinear dynamic analysis method is applied. By regarding SFT as an elastic-plastic vibrating system and inputting seismic acceleration records, numerical simulation results are obtained. The research results indicate that with the increase of the spring stiffness, the response of the tube decreases under the effect of the observed seismic force and the peak value appearance time of mid-span displacement response put off gradually. Besides, the effect of tunnel length on the displacement response is limited when the spring stiffness value is fixed. As the key to SFT design, the scope of stiffness design parameters are given in this paper. The research would provide a reference for seismic design and further study of SFT.

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Keywords: submerged floating tunnel; the tube body; random vibration; nonlinear dynamic analysis; dynamic response

1. Introduction

The Submerged Floating Tunnels(SFT) is a kind of passageway floating under the water surface, whose tubes consist of metal structure or reinforced concrete structure.When the buoyancy of tunnel tube is greater than its own gravity, cables are used for connecting the tunnel tube to the fixed underwater locations. The SFT can provide the possibility to cross those water areas that traditional transport forms can not do. Furthermore, the SFT bears not only deadweight and vehicle load but also other environmental dynamic loads (such as buoyancy, wave, ocean current,

*Corresponding author.Tel.: +86-181-1967-0189;
Email address: dongms@hfut.edu.cn

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earthquake, etc.), which is different from the constructions on the ground. That’s the reason why the SFT dynamic response under complex environmental loads has been chosen as the focus for researching the security and stability of SFT.

The seismic load effect, which is the most difficult problem to study, has been taken into consideration in many cases. As the earthquake disasters have serious effect on the security of SFT, experiments and theoretical exploration on the reaction mechanism of SFT structure under earthquake excitation are essential part during SFT researches. Martinelli [1] adopted the step-by-step dynamic analysis of discretized non-linear structural systems, and study the dynamic response of the SFT in the design scheme of Qiandao lake with seismic response spectrum method. The analysis of the dynamic response of SFT system under seismic load and the vibration characteristics of cables under forced excitation was carried out by Sun [2]. This research was based on the overall vibration of SFT and the local vibration of anchor cable, and a preliminary study on the passive control of cables has also been conducted. Kiyokawa [3] investigated the influence of fluid compressibility on seismic force, and gave the wave potential theory of the compressed fluid. It was shown that the fluid compressibility has a great influence on fluid force under conditions of deep water and high frequency. Based on a two-dimensional wave potential theory (i.e. Green's function method), Morita [4] studied the response of submerged floating tunnels to vertical seismic excitations by considering compressibility of sea water. Fogazzi [5] considered fluid-structure and soil-structure interaction effects and proposed a finite element analysis procedure for researching the seismic response of fixed cable type SFT. An example of an application was given concerning two kinds of SFTs with different seabed profile in his research.A uniformly modulated random process is used to model the multi-support seismic input for a given structure of large dimension undergoing limited plastic deformation for analyzing the dynamic response of SFT under seismic load by Luca [6]. Chen [7] investigated the dynamic characteristics of SFT under seismic wave passage effect by using commercial code ANSYS11.0 while Martire [8] studied seismic analysis of a SFT solution for the Messina Strait crossing by ABAQUS6.7 procedure and expounded the influence of different forms of anchor cables on SFT dynamic response. Xiang [9] used Hamilton principle for researching the vortex induced vibration and parametric vibration of tube and cables caused by current and analyzed the nonlinear vibration characteristics about cable and tube coupling system of SFT.

Based on the theory of elastic foundation beam, dynamic equations of submerged floating tunnel(SFT) tube under seismic force are presented. For investigating the influence of P wave, tunnel length and stiffness of anchorage system on SFT tube, the nonlinear dynamic analysis method is applied. By regarding SFT as an elastic-plastic vibrating system and inputting seismic acceleration records, numerical simulation results are obtained and the scope of stiffness design parameters are also given in this paper.

2. Physical model

The length of SFT can reach to ten kilometers or even more by consisting of many same tubes. For investigating the dynamic response of SFT tube under seismic load, a typical model of SFT is used in this paper, see Fig. 1. The whole dynamic system includes tubes and anchor systems. According to the researches of Sato [10,11], a beam on equidistant elastic supports can be considered as a beam on an elastic foundation, which is suitable for both static and dynamic loading with the same relative stiffness parameters. Therefore, the anchoring supports of SFT can be regarded as the continues supports with equal distances.